Development of the Fragment Separator Designs for RIA

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NSCL

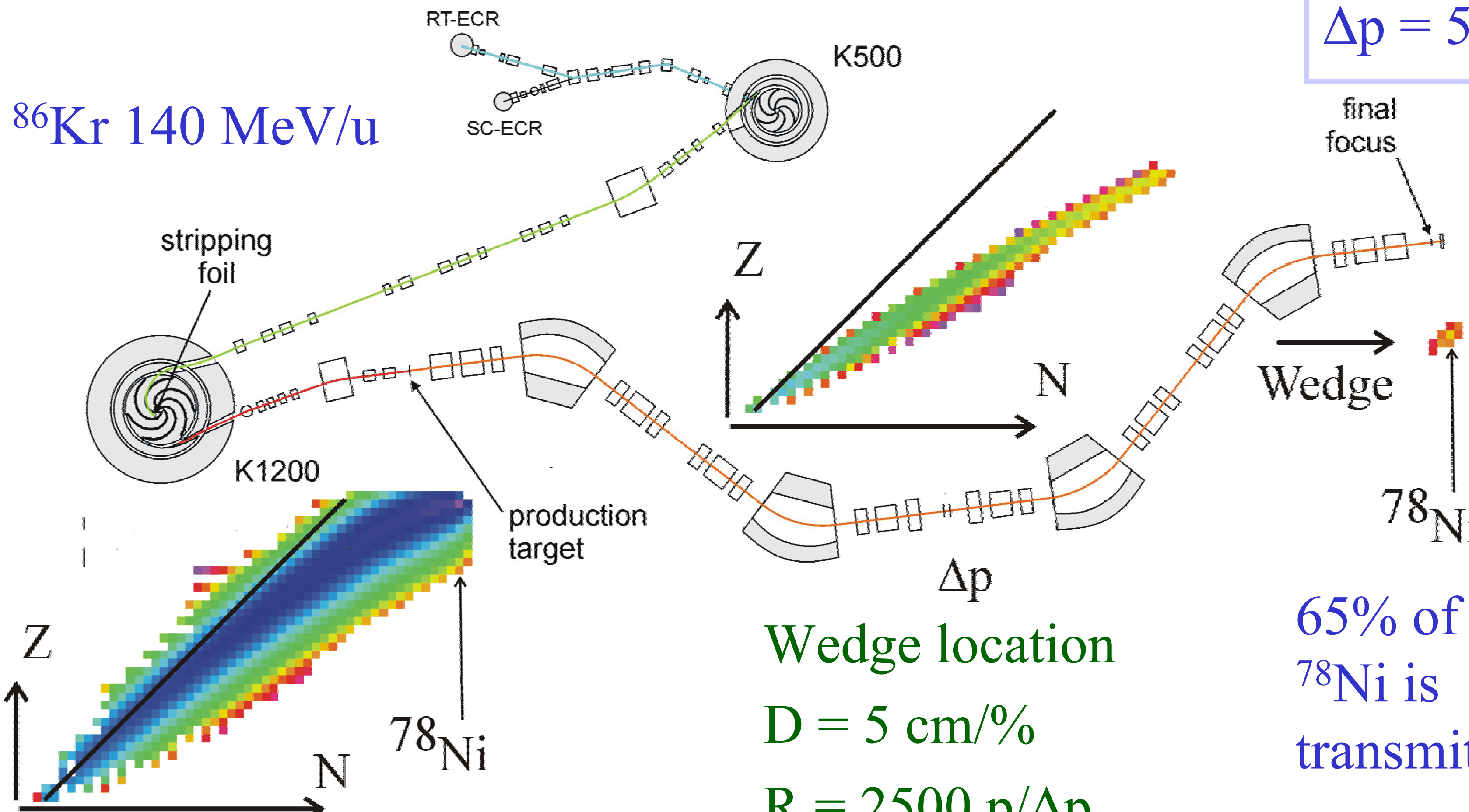
Overview of the Fragment Separation Technique

The NSCL Coupled Cyclotron Facility – A1900 Separator

8 msr

$\Delta p = 5\%$

^{86}Kr 140 MeV/u



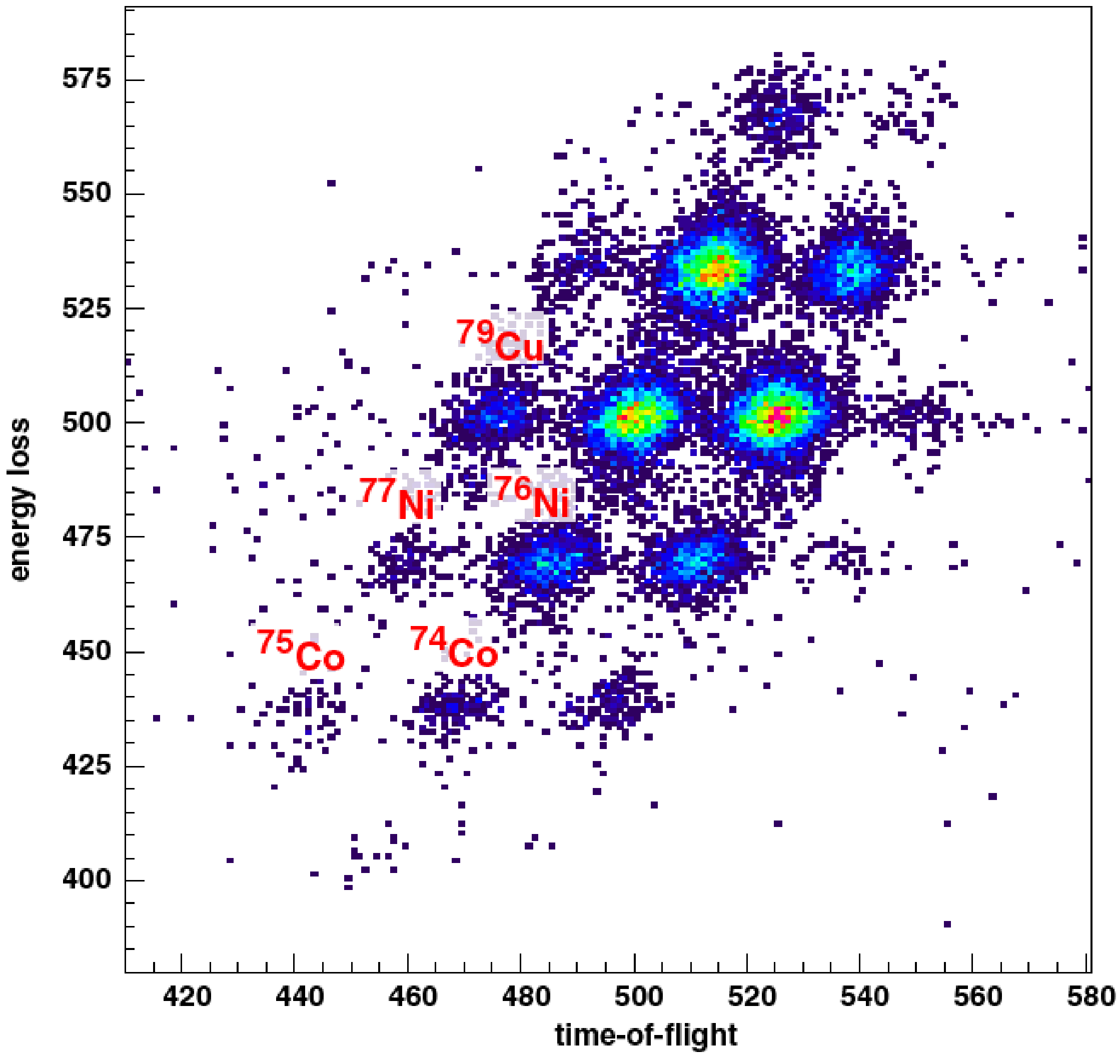
Wedge location

D = 5 cm/%

R = 2500 p/Δp

65% of the ^{78}Ni is transmitted

Sample Data from the A1900



140MeV/u

^{86}Kr

8 msr

5%

The NSCL has Extensive Experience in Separator Design

- The A1200 separator was completed in 1989 and was the heart of the NSCL radioactive beam program for 10 years. RNB experiments were more than 60% of the experimental program.

  Sherrill, Morrissey, Nolen, Winger NIM B56 (1993)

- The A1900 separator was designed to be optimized for the Coupled Cyclotron Facility. It was completed in 2001.

  Morrissey, Sherrill, Steiner, Stolz, Wiedenhoever NIM B204 (2003)

- The A1900 will be a testing ground for RIA fragment separator concepts.

LISE – Necessary Tool for RIA Separator Design

LISE 6.2.21

O. Tarazov, D. Bazin

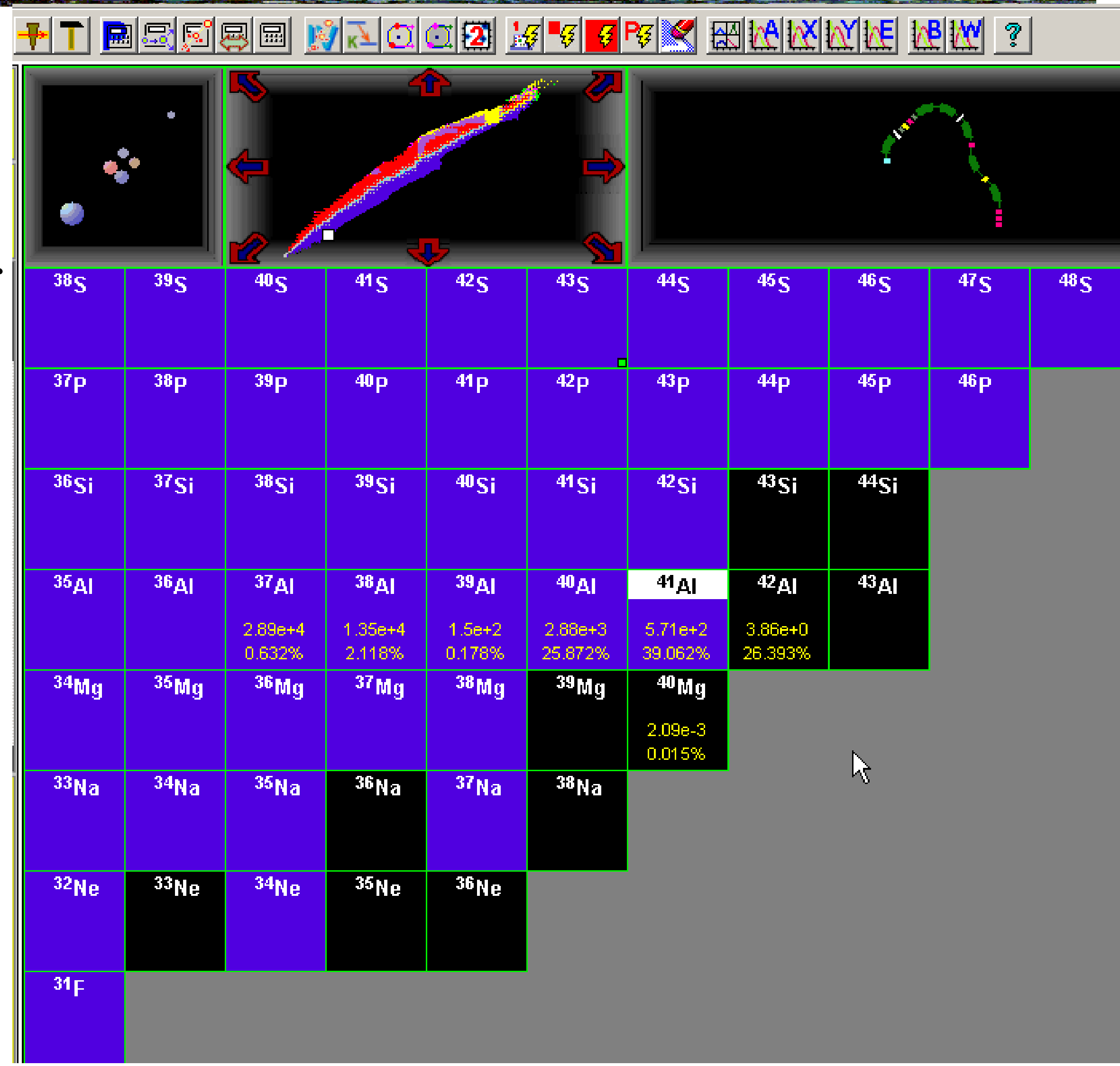
Allows a full first-order simulation of fragment separator designs including momentum compression and stopping in gas.

To Do List:

Verify current code

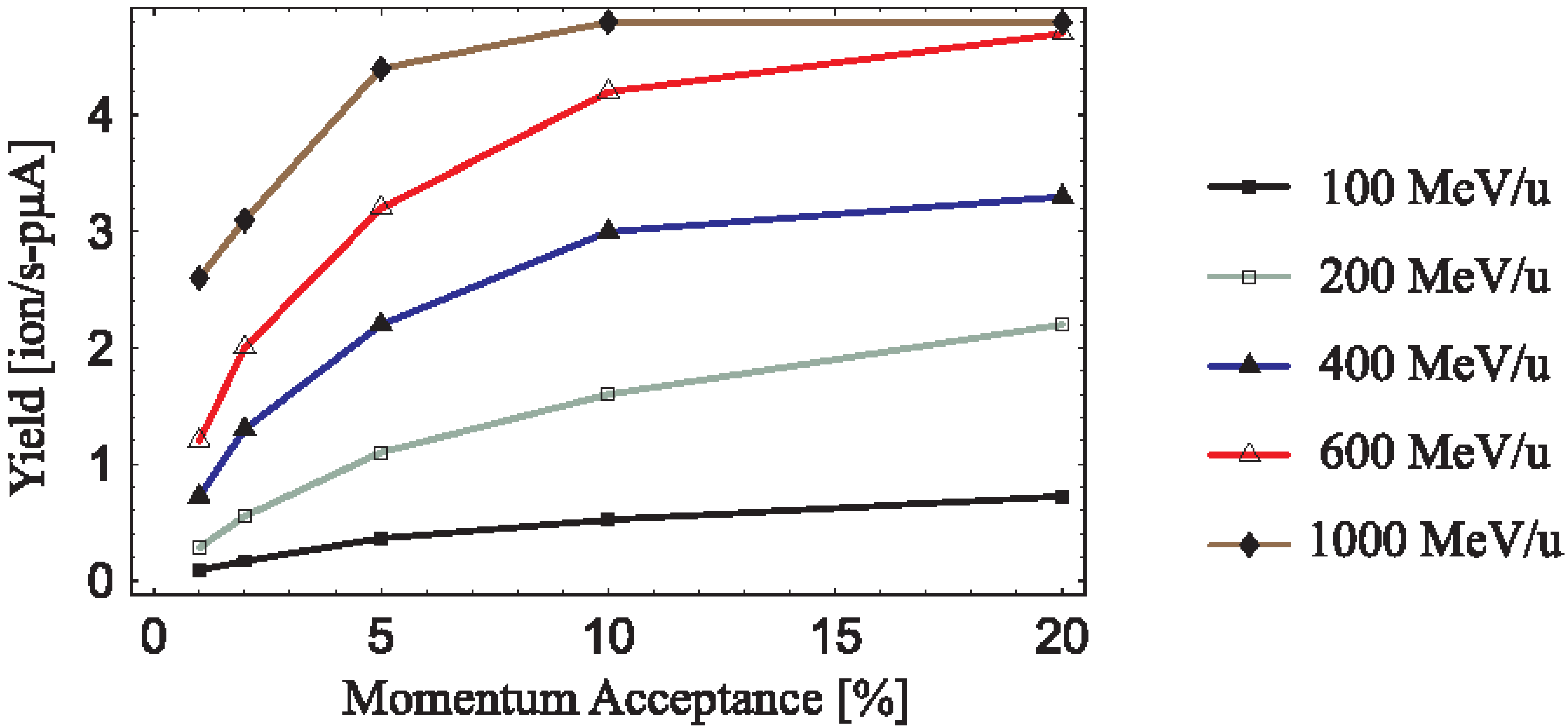
Fission

Monte Carlo



Yield vs. Fragment Separator Momentum Acceptance

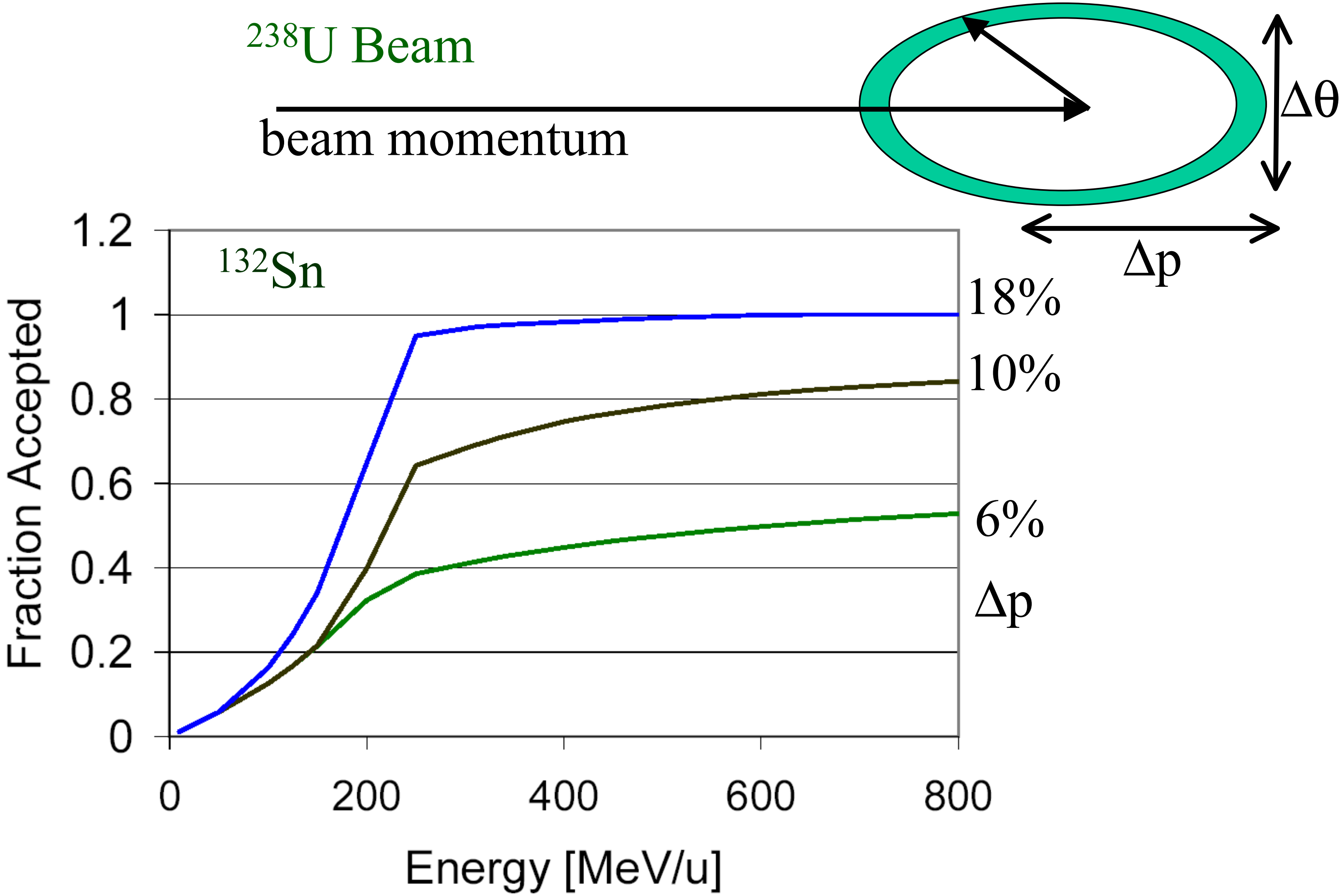
^{78}Ni production from ^{86}Kr+^{9}Be fragmentation



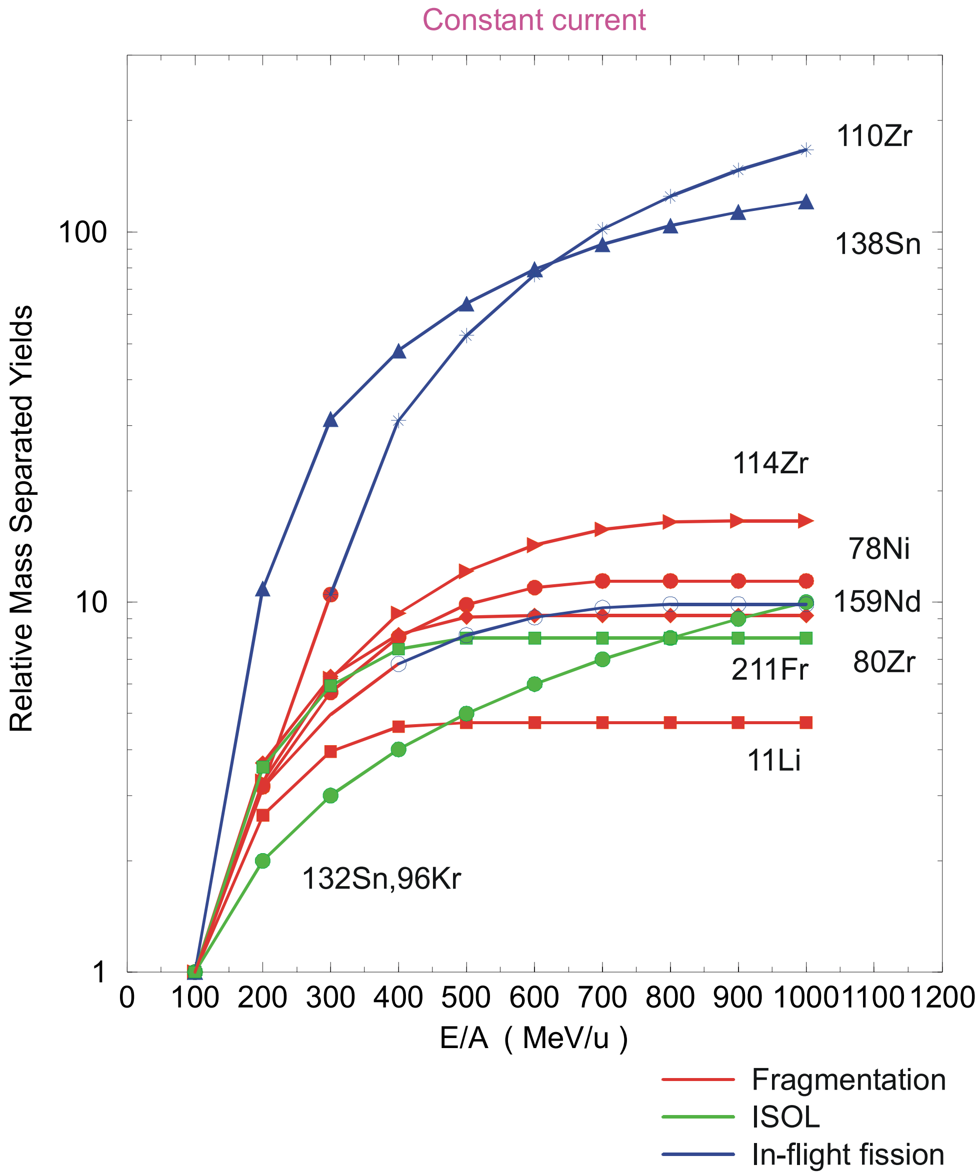
LISE 5.9

Production from secondary reactions are not included.

Yields for Projectile Fission (Schematic Model)



Energy Dependence of RI Production: RIA Example



The turn over point depends on the fragment separator acceptance.

A smaller acceptance fragment separator produces a later turnover.

Basic Design Goals for the RIA Separators

- Two Separators are needed in the RIA concept
  - High acceptance (12%,10 msr) to feed ions into the gas catching station.

→ Pre-separator → Separator → Momentum compression → Gas cell

  - Higher resolution (higher rejection of unwanted fragments) to feed ions to the high energy experimental area: (6%, 8msr)
- 10 T-m maximum rigidity is desirable for the most neutron rich fragments (10 Tm vs 8 Tm is a factor of 2 in yield for ^{41}Al from ^{48}Ca).
- Higher order aberrations must be kept low
  - Purity of the separated fragments
  - Stopping efficiency

Results of ion optical aberrations

Calculations done with LISE (initial spot size varied)

3mm aberrations

76% stopped in the cell

^{133}Te	^{134}Te 1.02e+5 0.003%
^{132}Sb 1.01e+3 0%	^{133}Sb 2.5e+6 2.091%
^{131}Sn 2.39e+3 0.011%	^{132}Sn 5.44e+5 11.344%
^{130}In 3.52e+2 0.026%	^{131}In 4.26e+4 18.989%
^{129}Cd 6.45e+1 0.066%	^{130}Cd 3.06e+3 23.913%

1 mm aberrations

81% stopped in the cell

^{132}Sb	^{133}Sb 1.06e+6 0.891%
^{131}Sn	^{132}Sn 5.81e+5 12.115%
^{130}In 2.55e-1 0%	^{131}In 4.83e+4 21.563%
^{129}Cd 1.74e-2 0%	^{130}Cd 3.42e+3 26.769%

Effect of degrader errors – 2 stage separator

No wedge defect

^{132}Sb	^{133}Sb 1.43e+6 1.195%
^{131}Sn 7.1e-7 0%	^{132}Sn 8.1e+5 16.901%
^{130}In 2.6e-1 0%	^{131}In 7.01e+4 31.283%
^{129}Cd 1.74e-2 0%	^{130}Cd 5.12e+3 40.005%

Wedge defect of 0.2%

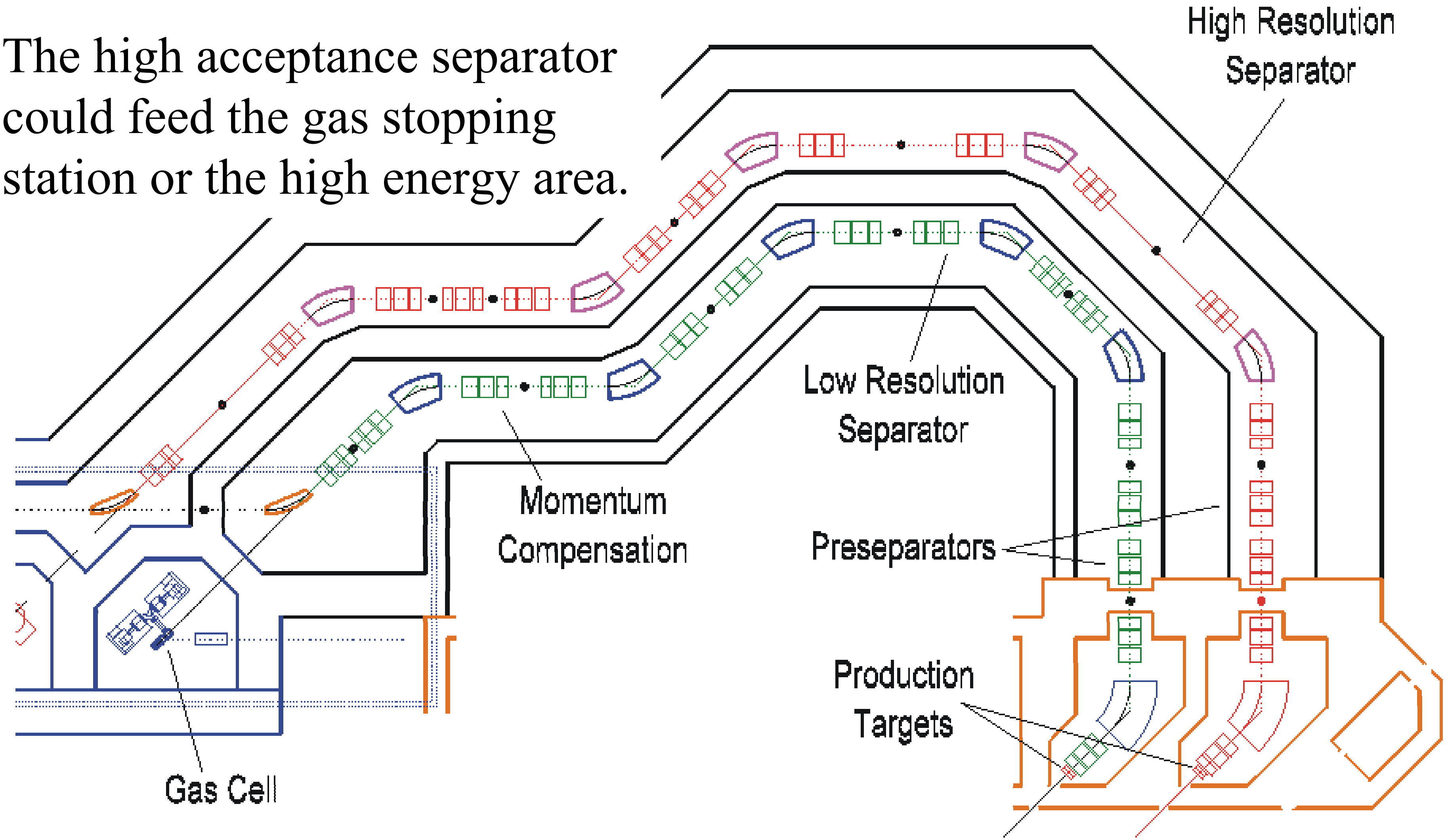
^{133}Te	^{134}Te 6.77e+3 0%
^{132}Sb 3.65e+1 0%	^{133}Sb 2.75e+6 2.3%
^{131}Sn 9.72e+2 0.005%	^{132}Sn 7.29e+5 15.218%
^{130}In 3.04e+1 0.002%	^{131}In 5.72e+4 25.51%
^{129}Cd 2.27e+0 0.002%	^{130}Cd 4.1e+3 32.017%

Wedge defect of 1.0%

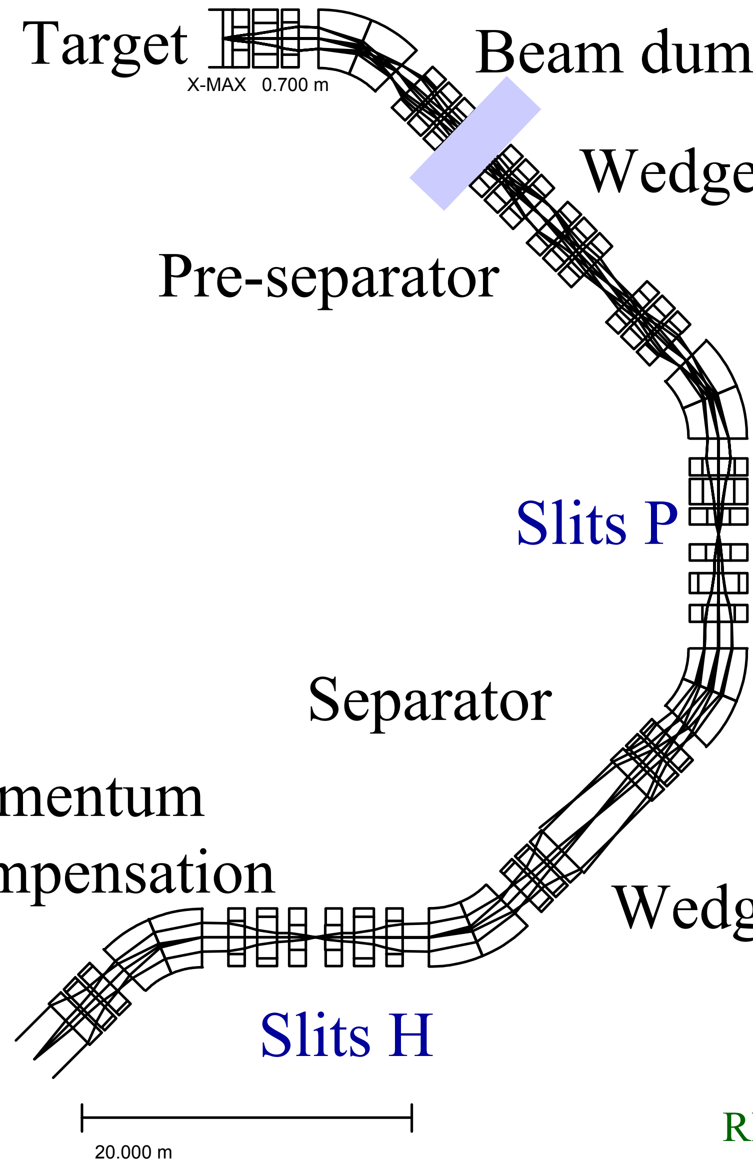
^{131}Te	^{132}Te	^{133}Te 7.57e+1 0%	^{134}Te 5.66e+6 0.185%
^{130}Sb 4.12e+1 0%	^{131}Sb 4.38e+5 0.045%	^{132}Sb 2.79e+6 0.748%	^{133}Sb 2.66e+6 2.23%
^{129}Sn 3.8e+2 0%	^{130}Sn 5.42e+4 0.07%	^{131}Sn 2.53e+5 1.179%	^{132}Sn 1.74e+5 3.624%
^{128}In 2.86e+1 0%	^{129}In 2.82e+3 0.045%	^{130}In 1.54e+4 1.136%	^{131}In 9.76e+3 4.355%
^{127}Cd 3.44e-1 0%	^{128}Cd 1.95e+2 0.035%	^{129}Cd 1.26e+3 1.283%	^{130}Cd 6.27e+2 4.901%
^{126}Ag 1.35e-3 0%	^{127}Ag 1.41e+1 0.027%		

A Possible RIA Separator Configuration

The high acceptance separator could feed the gas stopping station or the high energy area.



Optical Layout of the HA Separator



Fragments after Slits H

^{132}Sb	^{133}Sb 1.43e+6 1.195%
^{131}Sn 9.81e-7 0%	^{132}Sn 8.1e+5 16.902%
^{130}In 3.6e-1 0%	^{131}In 7.01e+4 31.284%
^{129}Cd 2.5e-2 0%	^{130}Cd 5.12e+3 40.006%

Fragments after Slits P

^{132}Te	^{133}Te 2.69e+2 0%	^{134}Te
^{131}Sb 4.77e+6 0.486%	^{132}Sb 7.5e+7 20.107%	^{133}Sb 1.03e+7 8.615%
^{130}Sn 1.94e-2 0%	^{131}Sn 9.52e+5 4.43%	^{132}Sn 1.88e+6 39.226%
^{129}In	^{130}In 1.74e+3 0.128%	^{131}In 1.01e+5 44.892%
^{128}Cd	^{129}Cd 1.89e+1 0.019%	^{130}Cd 6.04e+3 47.233%

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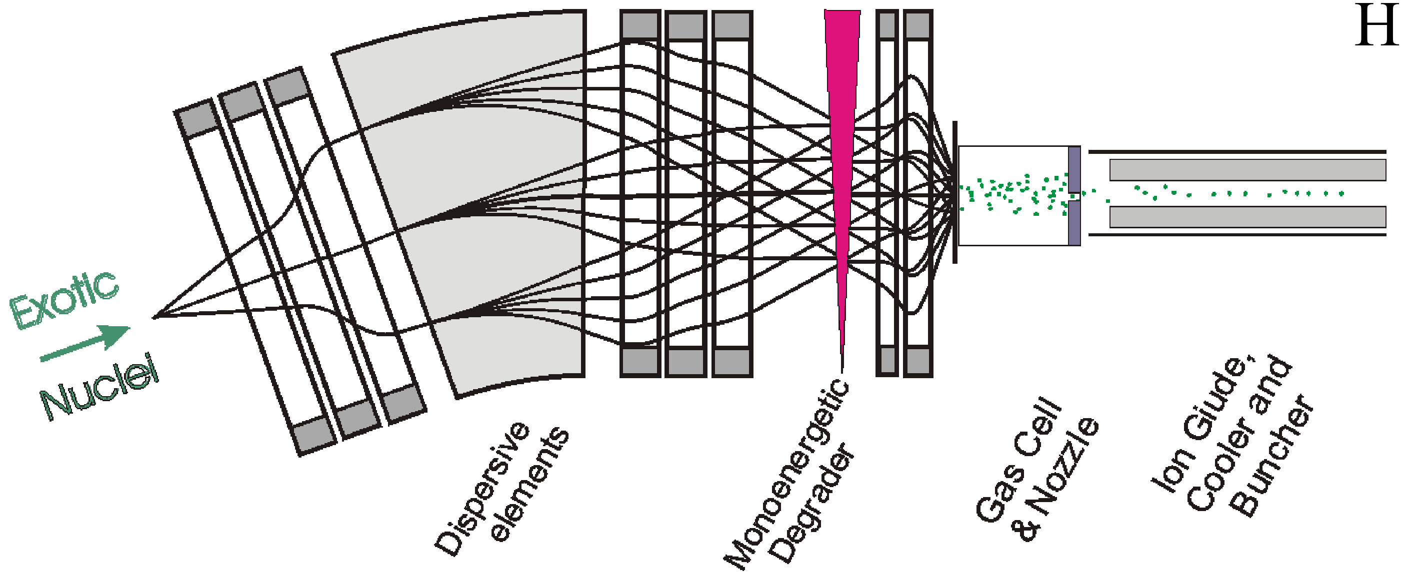
Momentum Compression Technique

H. Weick



Range straggling can be reduced to 10% larger than the range straggling of monoenergetic ions.
H. Geissel et al. NIM A282 (89) 247

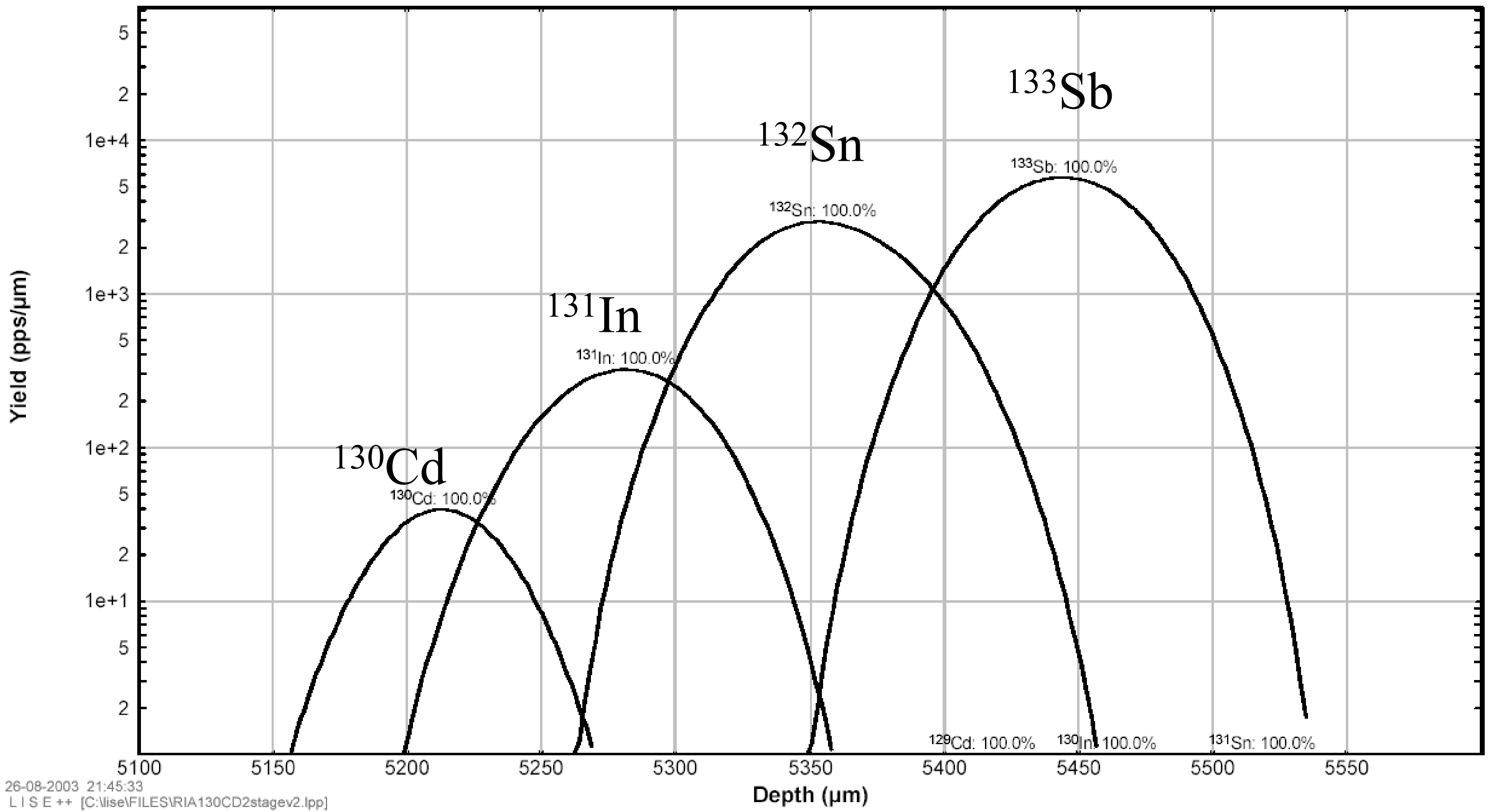
Minimum momentum compression:

$\delta_{min} = (Mx_o/D)\ (1\text{-}t/R)^{-1}$

$\delta_{min} = (1.0*.2/3.0)\ (1.25) = .08\ \%$

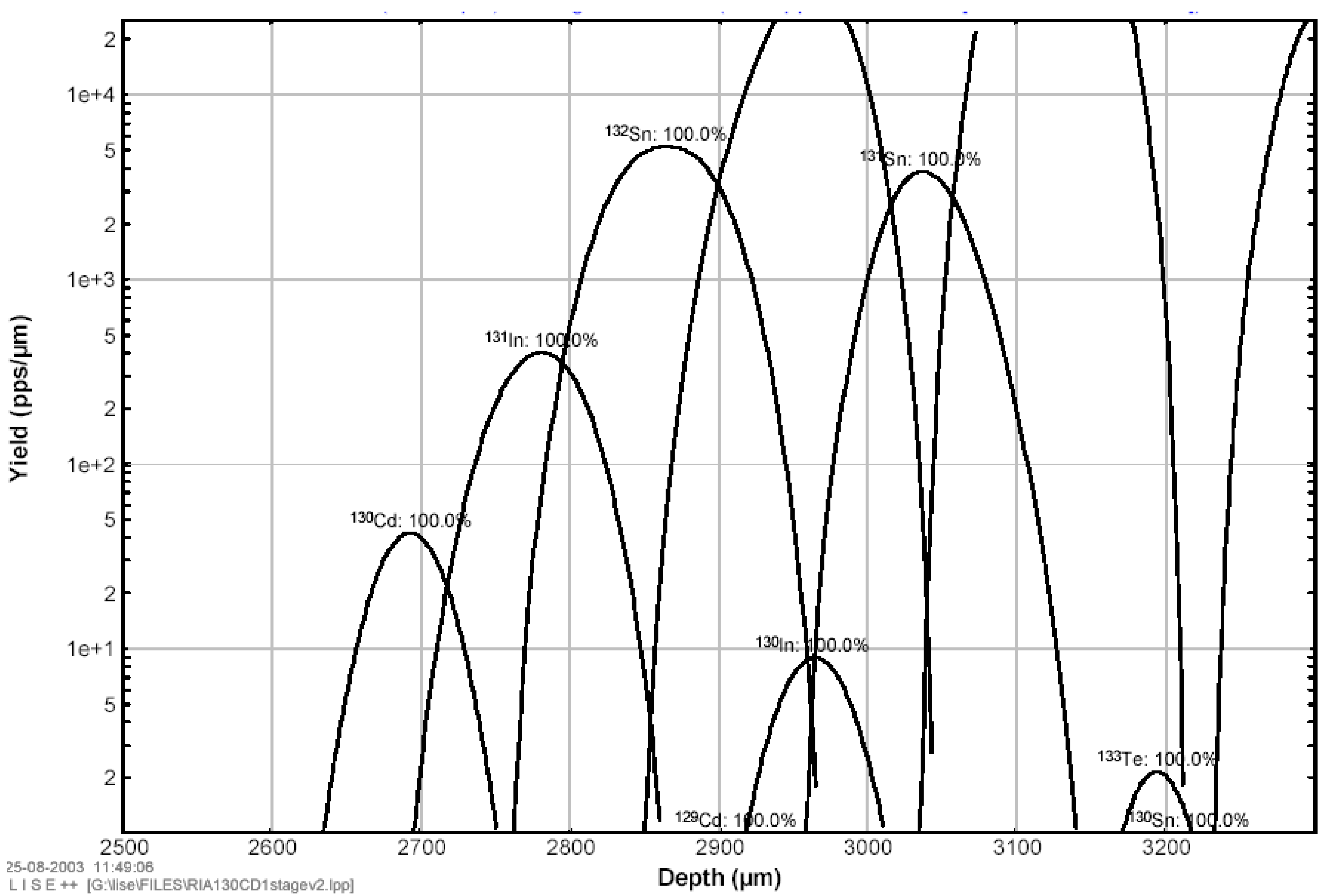
Range straggling limit corresponds to .1%

Implantation Depth of Fragments – 2 stage



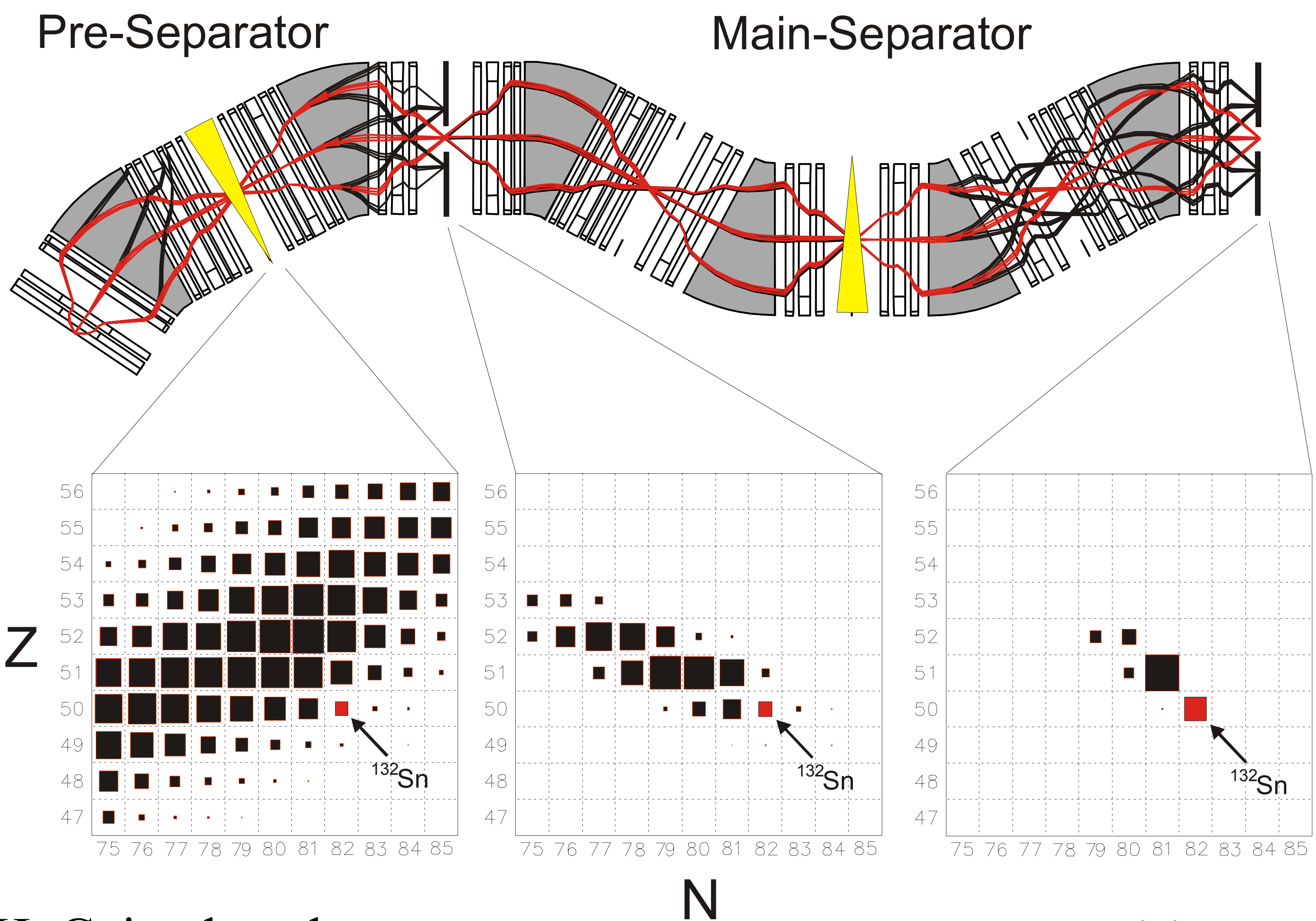
LISE 6.2.23

Implantation Depth of Fragments – 1 stage



LISE 6.2.23

GSI and RIKEN plan two separator stages



H. Geissel et al.

Pre-Separator First Order Optics

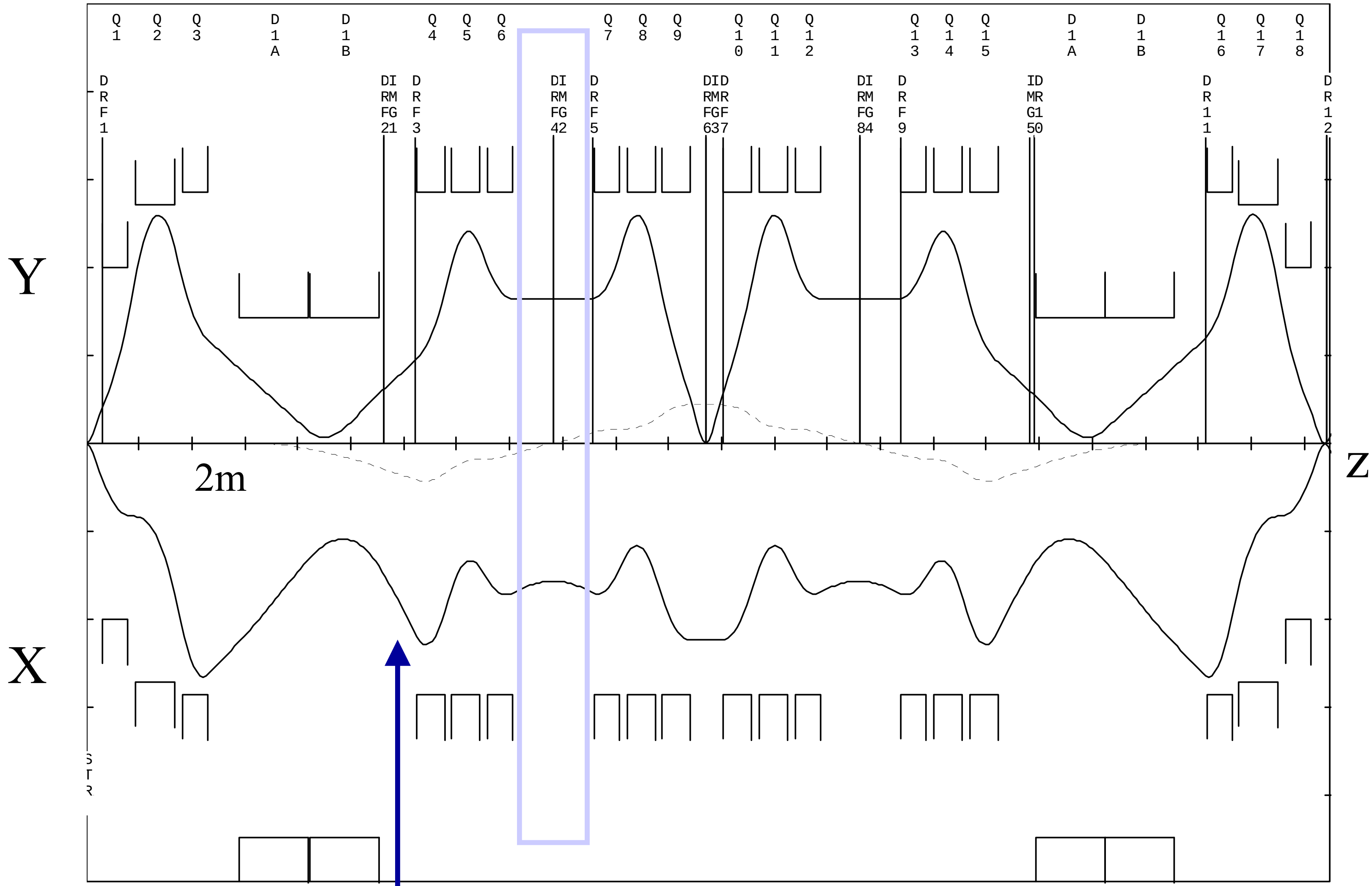
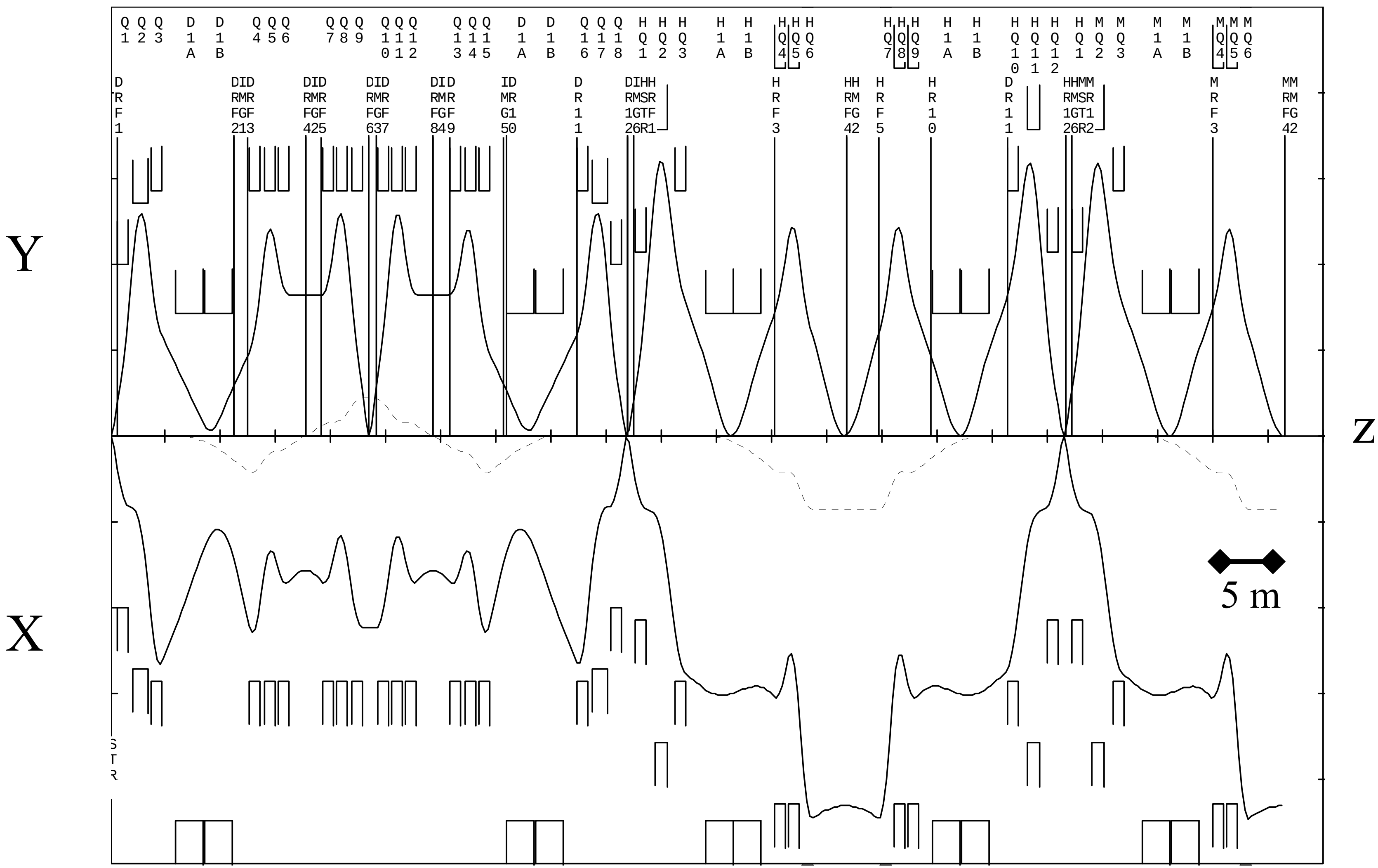


Image for beam catcher

Full High Acceptance Separator First Order Layout



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Fragment Separator R&D Issues

- Software development of the program LISE to be able to model all aspects of the separation and stopping process is underway and should continue.
- Preliminary designs have been investigated, but a full design of the separators is necessary to set the magnet parameters and civil construction details.
- A number of significant R&D issues remain.
  - Optimize acceptance (6% to 18%) while keeping aberrations at acceptable levels
  - Study radiation fields and damage on system components
  - Beam and fragment dump (isotope harvesting)
  - Wedge uniformity and momentum compression

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